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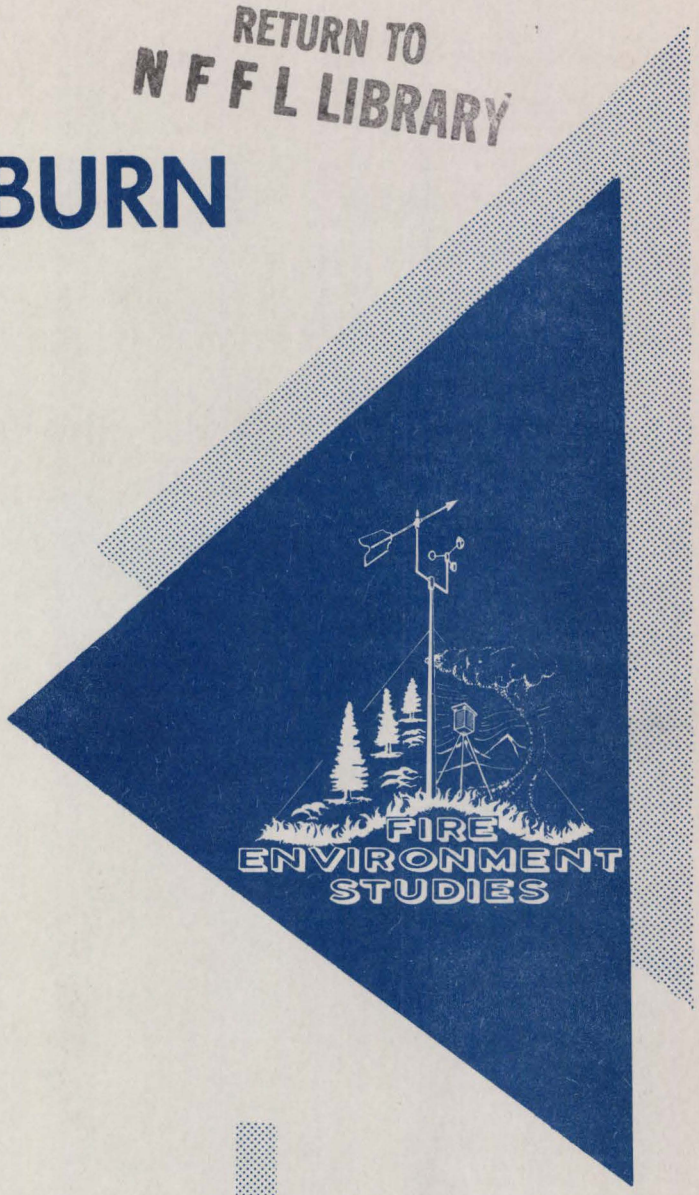
PRESCRIBED BURN FIRECLIMATE SURVEY 3·57



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C.M. Countryman

M.J. Schroeder

PACIFIC SOUTHWEST FOREST & RANGE EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR . . . . . BERKELEY CALIFORNIA

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FOREWORD

Fireclimate Studies--Their Purpose

Experience and research have taught firefighters a good deal about wildland fire. Its general relationship to weather, fuels, and topography are well known. Application of this knowledge to control of fire is frequently hampered by lack of information about the behavior of fire-climate in specific places--how wind, temperature, humidity, and fuel moisture are affected by topography, water bodies, season, and the fire itself. The existing system of weather stations provides enough information for general weather forecasts but not enough to define local fire-climate patterns. The stations are relatively few, widely spaced, and seldom equipped with recording instruments. They gather only momentary samples of weather conditions and provide no information on the way fire itself affects the patterns.

To obtain this needed information, this Experiment Station has started studies aimed at establishing some of the principles controlling local fireclimate patterns and the effect of fire on these patterns. A four-pronged attack will be made on the problem:

1. Semi-permanent fireclimate surveys wherein distinct topographic types will be intensively instrumented for one or more years primarily for the study of variations in local fire-climate patterns in relation to more general weather patterns.

2. Temporary or mobile surveys that will permit exploratory studies of fireclimate patterns around prescribed burns and wildfires and short-term detailed studies of various phases of broader scale fireclimate patterns.

3. Analysis of existing fire and weather records to establish, if possible, the relation of pattern of past fires to weather patterns.

4. Controlled laboratory studies aimed at determination of the fundamental laws governing fireclimate patterns and effects of fire on these patterns.

ABSTRACT

Prescribed burn 3-57 was the third of four prescribed burns studied in 1957. This burn was selected for study because of the known occurrence of downslope daytime winds in this general area. There is little quantitative information available concerning these winds.

During the period of the survey downslope winds occurred every afternoon and were much stronger than those that could be expected with more usual up-slope thermal winds. When the area was burned the wind pattern essentially controlled the fire behavior pattern. Little effect of the fire on the wind flow pattern was noted.

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THE SURVEY AREA

This prescribed burn was made on the Ford Ranch property in Lake County about 150 miles north of San Francisco, California and about 60 miles from the Pacific Ocean. All of the burn was on a generally east-facing slope on the west side of Cache Creek valley (fig. 1).

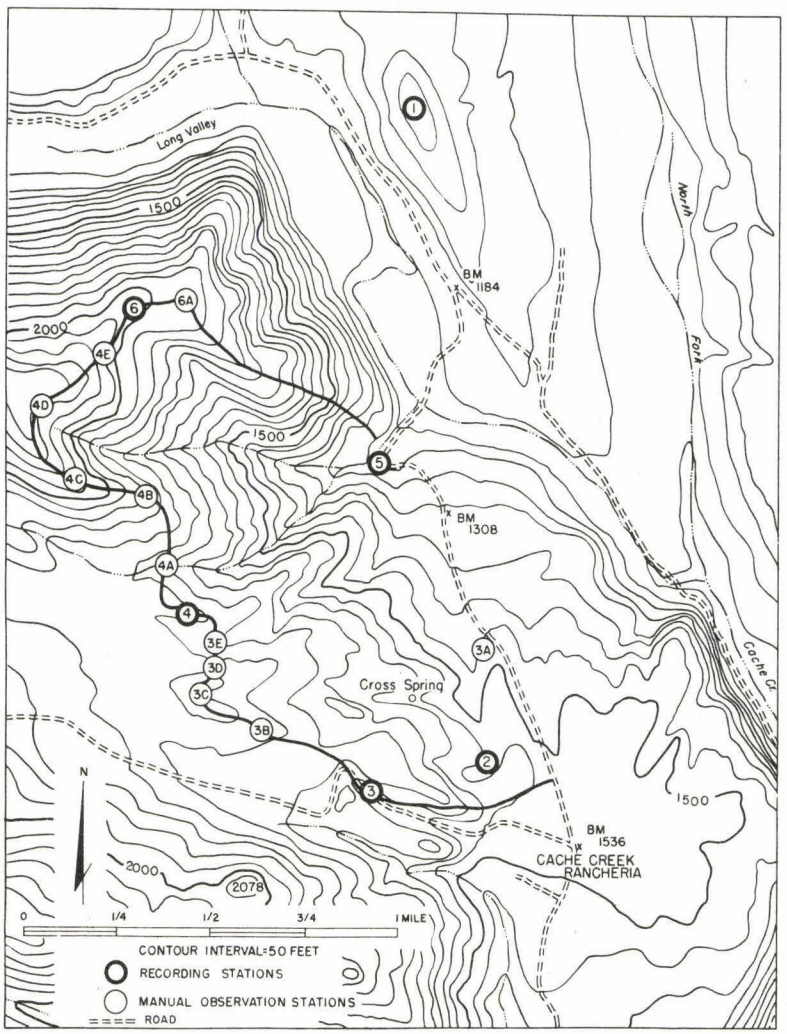

Figure 1.--Prescribed Burn 3-57, August 19, 1957

The valley floor in this area is about three-fourths mile wide, with little stream gradient. The 400-acre proposed burn area was on moderately steep slopes (fig. 2) that ranged in elevation from 1,100 to more than 2,200 feet.

Dense oak-woodland predominated in the southeast part of the area and along the road used for the east fire line (fig. 1). Below BM 1308 the heavy cover gave way to grass and scattered oaks (fig. 3). The main part of the burn area was covered with a moderate to dense stand of brush consisting chiefly of chamise, scrub oak, manzanita, and scattered digger pine (fig. 4).

Figure 2.--Slopes were moderately steep in the burn area.

Figure 3.--Fuel types below B. M. 1308.

Figure 4.--Typical fuels on the main burn area.

SURVEY PROCEDURE

Six sites were selected for the available wind-recording equipment. Most of the interior of the burn was inaccessible so that it was necessary to install the stations around the perimeter. Station 1 (fig. 1) was placed at a well-exposed site on a ridge at the junction of Long Valley Creek and Cache Creek. We estimated that this station was far enough from the burn that it would not be affected by the fire. Station 2 was on a low dam on a small drainage in the southeast corner of the burn. This station was somewhat sheltered by tall trees on the east and northeast but reasonably well exposed to wind from other directions. Station 3 was placed in a narrow draw on the southern edge of the burn. The station was sheltered by the topography to the southwest and northeast. Station 4 was located on the south side of the largest and best defined drainage within the burn boundaries. This station was very well exposed to winds from all directions (fig. 1). Station 5 (fig. 3) was in an open grassy area at the mouth of largest drainage. Station 6 (fig. 4) was located on the main ridge separating this drainage from Long Valley Creek. Hygrothermographs were placed at stations 1, 2, and 6 to record temperature and humidity.

In addition to the six recording stations, 11 other sites were selected (fig. 1) around the burn where readings were made manually to supplement the recorded observations. Wind speed and direction, temperature, and humidity were measured at these points.

Observations were started August 14, 1957 and continued until August 20. The area was burned August 19.

GENERAL WEATHER PATTERN

The survey was conducted during a period when daytime temperatures were slightly above normal. The temperature trend was generally upward during the first part of the period when maximum temperatures were in the low and mid 90's. Highest temperatures, generally in the high 90's, were observed at most stations in the area on August 17 and 18.

Though the air flow aloft over central California remained west-southwest and southwest during the survey, a major change in the upper air pattern over the northeast Pacific was observed during the period. At the beginning of the period (fig. 5) the contour pattern at 500 millibars (about 19,000 feet) showed a strong high pressure ridge in the northeast Pacific extending north to Alaska. A low pressure trough extended from Vancouver Island southwestward, and a high was located over the southwestern states. During the succeeding days the north portion of the ridge extended further northward over Alaska and northwest Canada. The

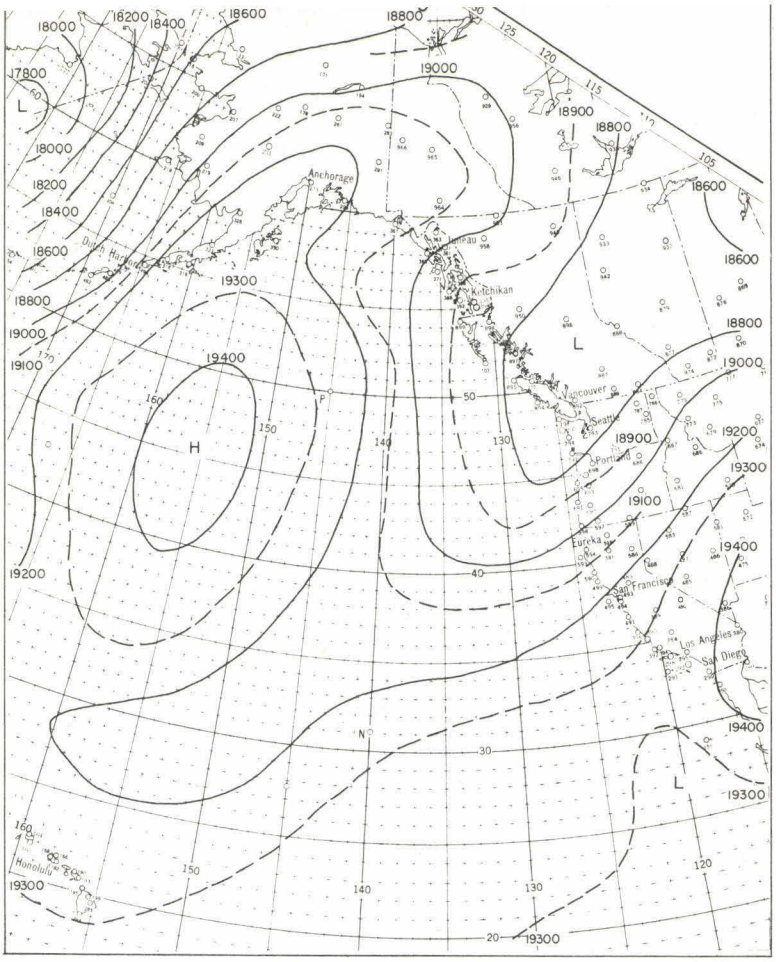

Figure 5.--Contour chart of 500 millibar surface, August 14, 1957, 1600 PST.

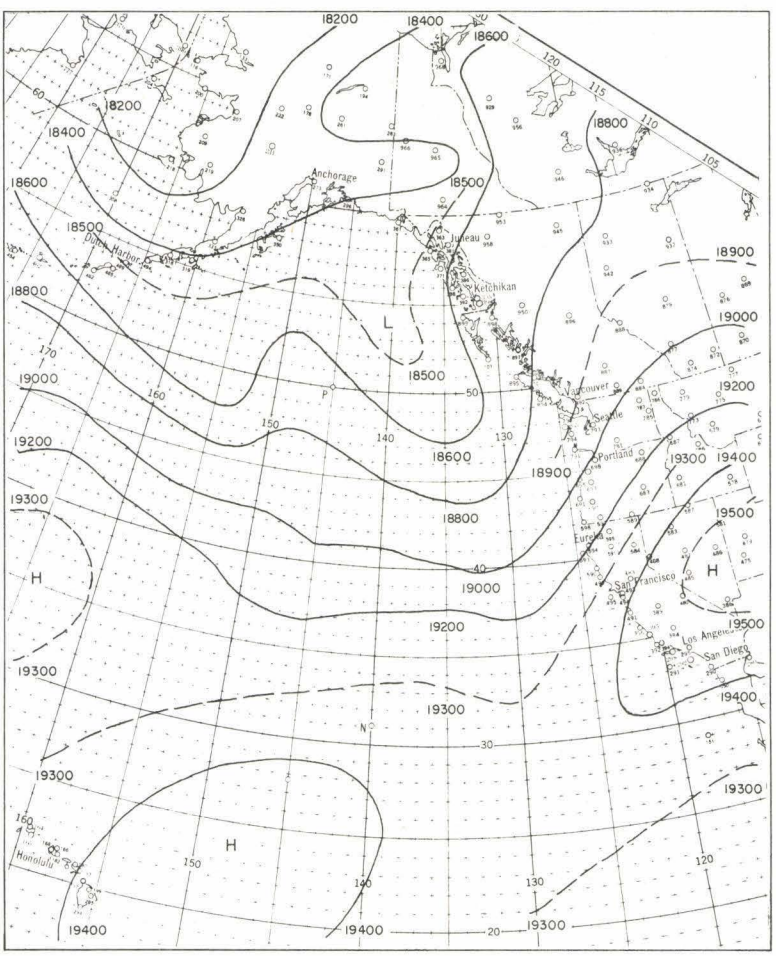

Figure 6.--500 millibar chart, August 18, 1957, 1600 PST.

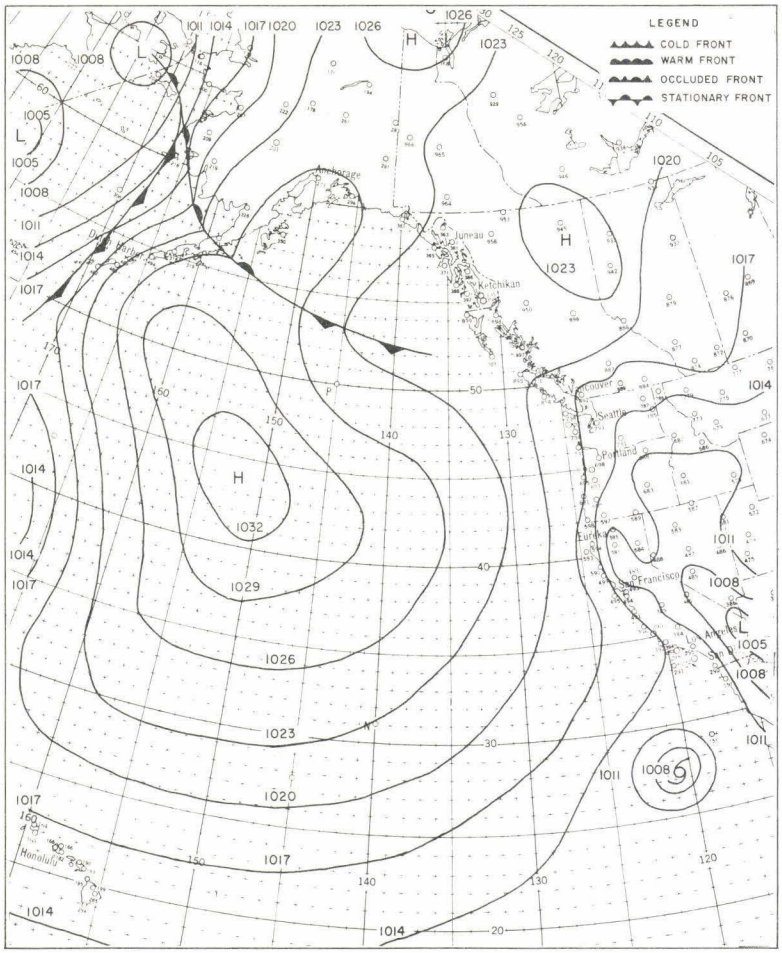

Figure 7.--Surface isobar chart August 14, 1957, 1600 PST.

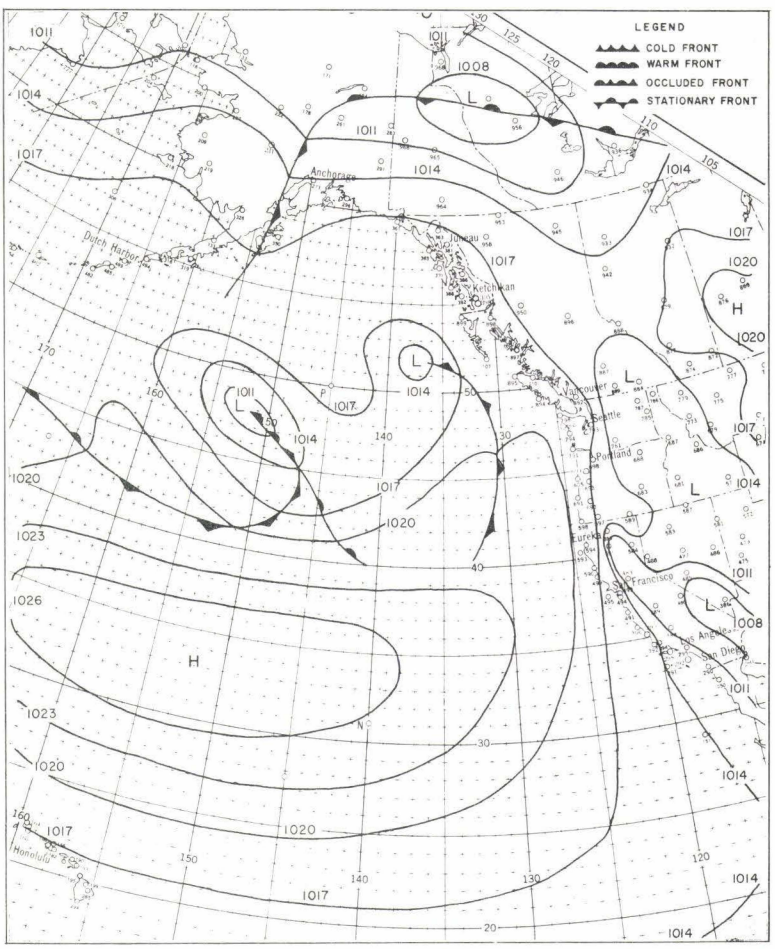

Figure 8.--Surface isobar chart August 18, 1957, 1600 PST.

ridge then split, and a succession of lows moved eastward between latitudes 40 and 50. Figure 6 shows the 500 millibar contour pattern on the afternoon of August 18. The 700 millibar charts (about 10,000 feet) showed similar changes in the contour pattern.

The changes in the upper-air pattern were reflected on the surface weather map. A high pressure area was located in the northeastern Pacific on the afternoon of August 14 (fig. 7). The following day a low pressure system developed almost in the same location. During the succeeding days this low moved very slowly northeastward while another low moved eastward near latitude 45°N from south of the Aleutians. In advance of the first low a slight ridge of high pressure was pressed eastward toward the coast of Washington, Oregon, and northern California. Since the usual summertime thermal trough in the central valley of California persisted throughout the period, this ridge resulted in a stronger pressure gradient across the survey area on August 18 and 19. The surface weather pattern for the afternoon of August 18 (fig. 8) shows that the eastern Pacific high pressure area was located much farther south than at the beginning of the survey period.

The upper-air observations at Oakland showed relatively minor changes in the temperature structure of the lower atmosphere during the period. The only significant change was an increase in instability in the layer above the marine inversion, particularly from 900 to 700 millibars. The temperature differences between the 900 and 700 millibar levels increased about 7° F. from the afternoon of August 14 to the afternoon of August 19. These changing conditions were recognized at the time the forecast for the day of the burn was made. As a result the forecast called for a convection column extending to about 10,000 feet. Observations from an aircraft during the burn indicated that the column actually extended to about 7,500 feet.

RESULTS

Local Fireclimate Patterns

During the time the survey was in progress, our data showed that the wind patterns in this area deviated in a major way from the classic pattern of up-slope, up-canyon winds during the day and down-slope, down-canyon winds at night. Shortly after sunrise there was a general up-slope movement of air over the burn area (fig. 9). At the higher and more exposed areas (Stations 1, 4, and 6) the wind was from a northerly direction or generally down the main Cache Creek drainage. Wind speeds were light, averaging 2 to 3 miles per hour. Calm periods were frequent.

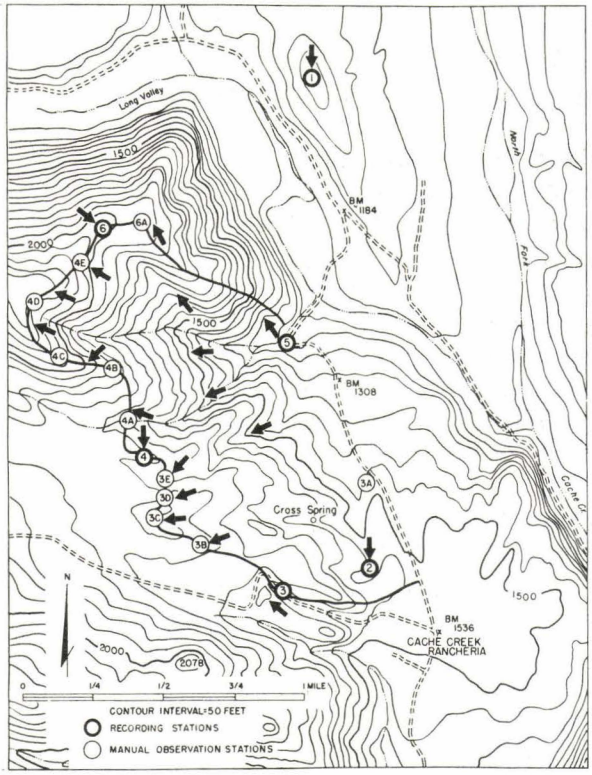

Figure 9.--Wind pattern, Prescribed Burn 3-57, 0800 hours.

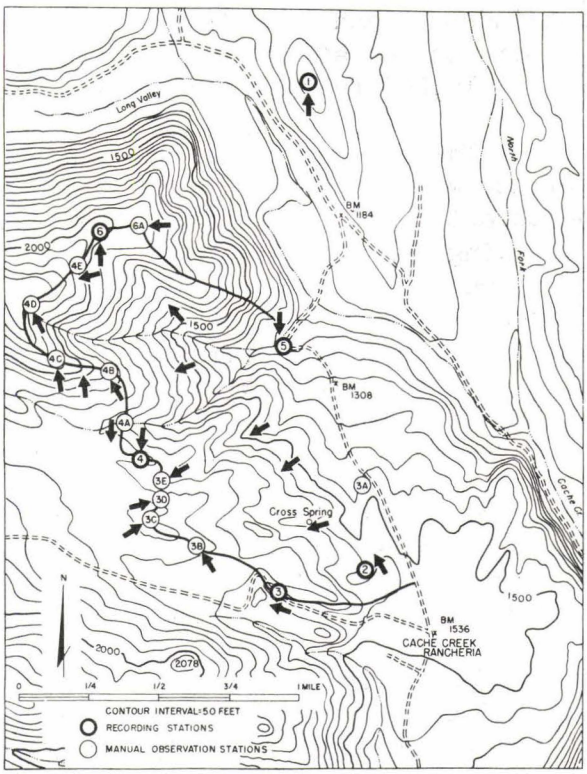

Figure 10.--Wind pattern, Prescribed Burn 3-57, 1100 hours.

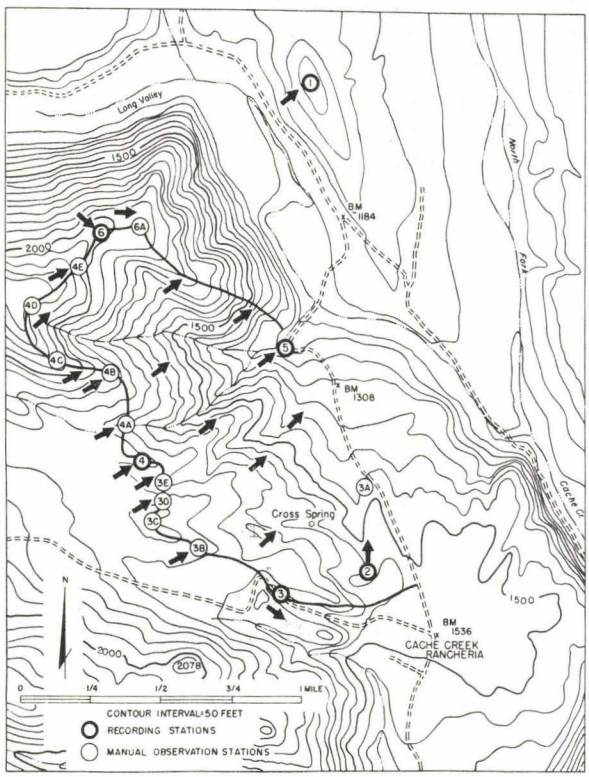

Figure 11.--Wind pattern, Prescribed Burn 3-57, 1200 hours.

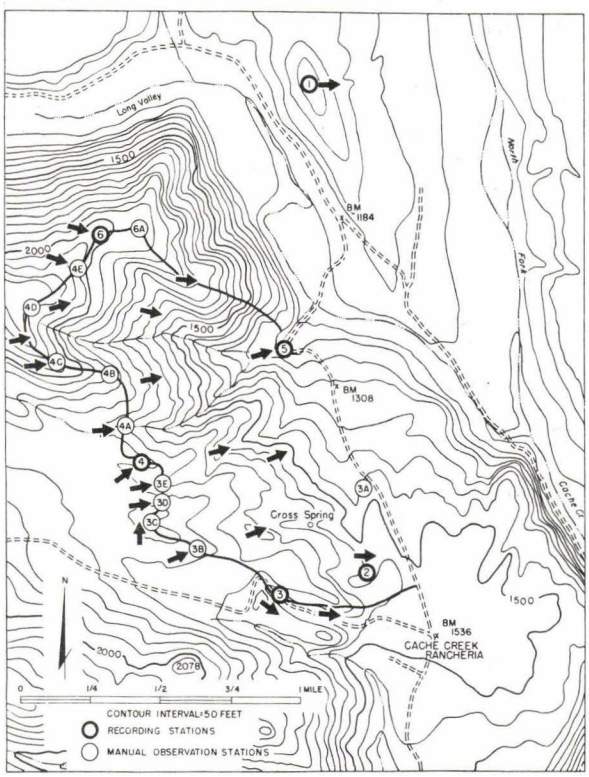

Figure 12.--Wind pattern, Prescribed Burn 3-57, 2000 hours.

This same sort of wind pattern continued over much of the burn area in the early forenoon hours. In the Cache Creek Valley and at the higher more exposed stations the wind tended to veer from the north through east to more southerly directions. By 1100 hours the more usual up-slope, up-canyon was evident (fig. 10). Wind speeds continued to be low, usually less than five miles per hour.

Between 1100 and 1200 hours the wind switched rather quickly to the southwest or west and increased in speed. By 1200 hours this westerly flow was well established and downslope winds prevailed over the entire burn area (fig. 11); the westerly down-slope wind pattern continued throughout the afternoon. Wind speeds also changed as the day progressed, increasing from 5 to 6 m.p.h. at 1200 hours to 15 to 18 m.p.h. by 1800 hours. After sundown wind speeds dropped off gradually until more normal down-slope and down-canyon drainage winds predominated (fig. 12).

The wind flow pattern at Station 3 was illustrative of the channeling effect topography can have on local wind movement. This station was located in a narrow canyon running approximately northwest and southeast. Ridges on each side of the canyon were about 150 feet above the canyon floor for a considerable distance on either side of the station. Air movement was thus restricted almost entirely to up- and down-canyon flow. During the early forenoon, while up-slope winds prevailed over most of the burn area, the wind direction at Station 3 was from the southeast, also up-canyon but almost at right angles to the wind direction in the less confined area of the burn (fig. 9). When the wind shifted to southwest and west over the rest of the burn area, wind direction at Station 3 was down-canyon from the northwest, again nearly at right angles to the more general wind flow of the area (fig. 11). Up-canyon winds were very light at this station but down-canyon winds averaging up to 8 m.p.h. were sufficient to have a significant effect on fire behavior.

Effect of Synoptic Weather on Local Fireclimate Pattern

The large change that took place in the synoptic weather pattern during the August 14 to August 19 period (fig. 5, 6, 7, 8) was reflected by only minor changes in the wind pattern on the burn area. The wind shift to down-slope flow occurred about one hour earlier on August 19 and the wind tended to be somewhat more northwesterly in direction. Wind speeds during the afternoon of August 18 and 19 were slightly higher than on previous days. Temperature and humidity remained about the same.

Fire Weather Forecast

Utilizing the detailed observations made on the burn area and general weather data and forecast from the U. S. Weather Bureau we were able to prepare the following detailed fire weather forecast for the day of the burn.

Fire Weather Forecast for Prescribed Burn 3-57, August 19, 1957

"The weather and wind patterns observed during the past several days will continue today with very little change. Skies will remain clear. The maximum temperatures will be 93-95 and minimum relative humidities 14-16 percent, occurring about 1530P. The temperatures will rise rapidly and humidities fall rapidly during the forenoon until around 1000P and then change more slowly. The temperatures at 1200P will be around 90° and the humidity around 20 percent. Minimum temperatures tomorrow morning 50-65 and maximum humidities 55-65 occurring about 0600P.

"Winds during the forenoon will be blowing up the canyons and draws, NE, E, or SE depending upon the orientation, at speeds of 2-4 mph. Between 1000 and 1200P the influence of the prevailing W to SW gradient wind will become stronger and result in a shift in the local winds to mostly down canyon. Directions will vary from SW-W-NW again depending upon the orientation (see map). Winds will become stronger after the shift. Speeds will be 8-14 m.p.h. at higher elevations on the west side of the area with gusts as high as 20 m.p.h. On the east side of ridges and near the top of steep slopes roll eddies will form. Conflicting wind currents along Cache Creek Valley and Long Valley could create erratic wind patterns in the area east of Station 5.

"This general wind pattern will continue during the afternoon and even during the evening hours except that at the lower elevations speeds will drop off quickly after sunset. At the higher elevations speeds will remain 6-12 m.p.h. until near midnight and then decrease to 2-4 m.p.h.

"The time of the wind shift from down canyon to up canyon tomorrow morning will be around 0600P.

"Slight cooling aloft, coupled with maximum temperatures in the mid 90's will result in a relatively unstable layer at least 10,000 feet thick. Thus a rather tall convective column may be expected."

Actual weather conditions on the burn were very close to predicted values. The up-slope thermal winds continued until about 1000 hours when the wind direction shifted to westerly and picked up rapidly in speed to approximately that predicted.

Fire Behavior

The firing plan for this prescribed burn called for firing to begin about 1100 hours along the road used for the northeast fire line. After this section was fired the perimeter firing was to be carried along the constructed fire line from its junction with the road near Station 2 (fig. 1), across the upper side of the burn, and back down to Station 5. This plan was made before the survey was started and apparently was based on the assumption the main fire run would be up-slope.

Actual firing started as planned at about 1100 hours. Because down-slope westerly winds had already set in by this time there was little success in getting the fire to spread away from the road in the woodland type between Station 2 and Station 5. Firing was then started near Station 3B and carried on around the burn to Station 6A. Along this section of line the fire took hold immediately and under the influence of the westerly winds ran rapidly down-slope (fig. 13, 14, 15, 16, 17). The fire crossed the road fire line in several places and continued to burn toward Cache Creek. More serious, however, were hundreds of spot fires that started on the inaccessible slopes on the east side of Cache Creek (fig. 1). These fires quickly coalesced into a wide fire front (fig. 18) which ran rapidly toward the east and burned several thousand acres before being brought under control on August 20.

Figure 13.--Prescribed burn 3-57 at 1134 hours.

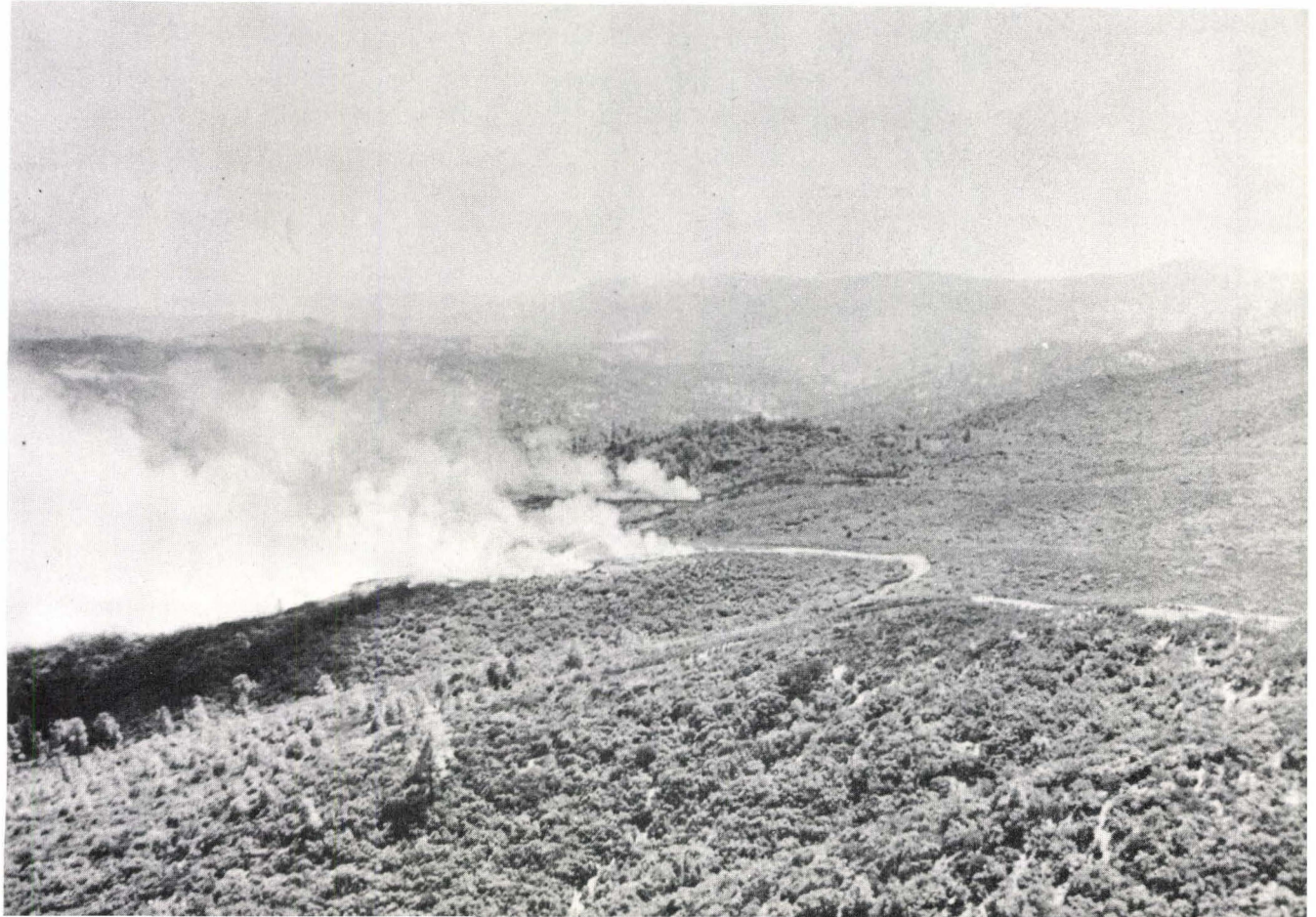

Figure 14.--Prescribed burn 3-57 at 1141 hours.

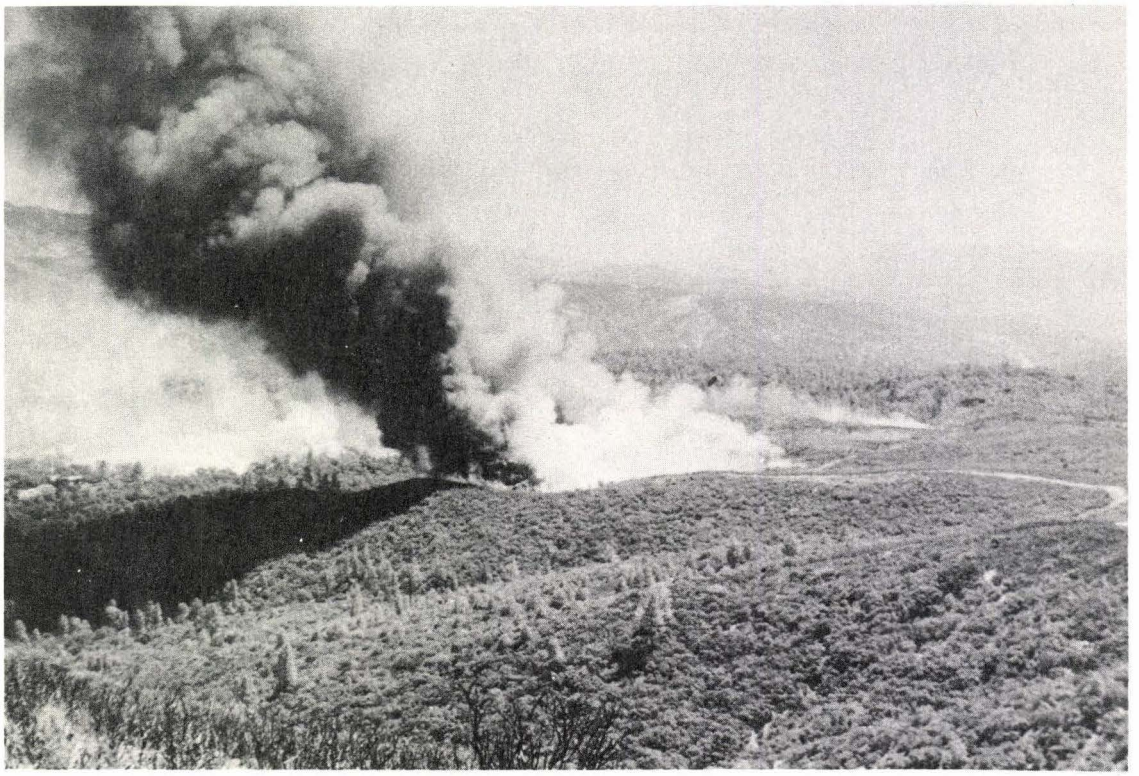

Figure 15.--Prescribed burn 3-57 at 1145 hours.

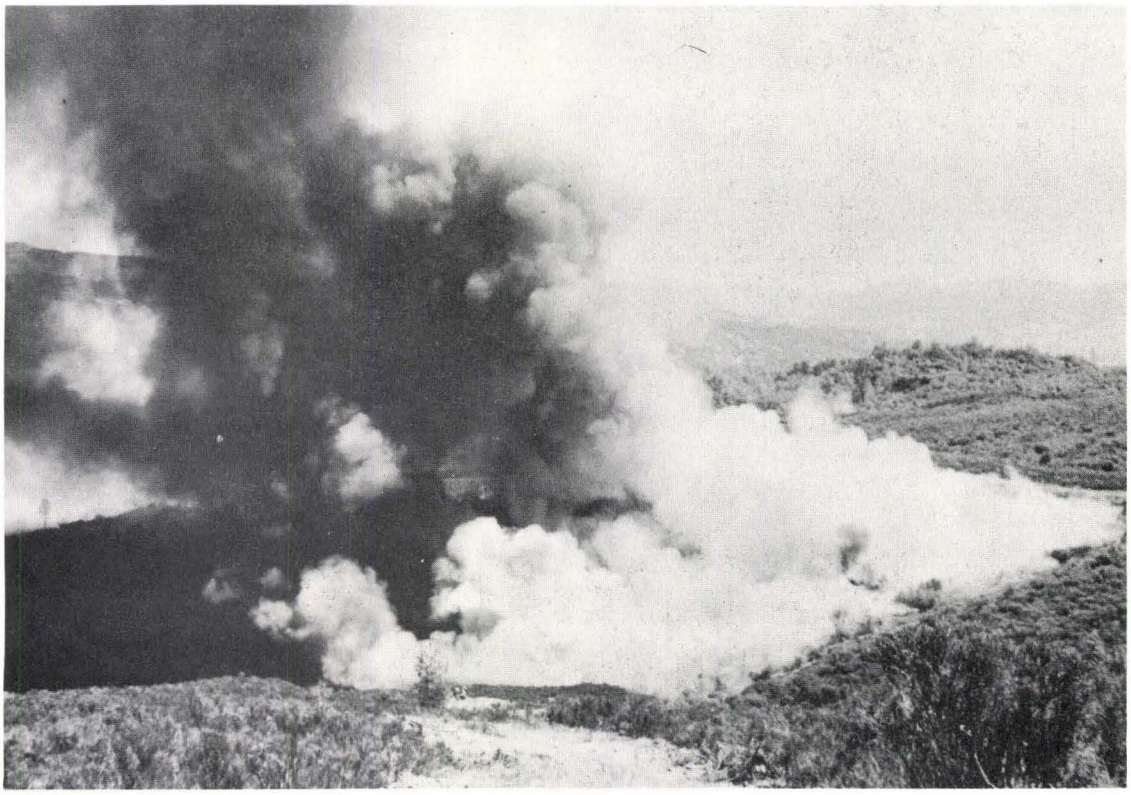

Figure 16.--Prescribed burn 3-57 at 1212 hours.

Figure 17.--Prescribed burn 3-57 at 1236 hours.

Figure 18.--Numerous spot fires across Cache Creek coalesced into a wide fire front which ran rapidly to the east.

The wind pattern on this prescribed burn was the dominant factor controlling the behavior of the fire. The down-slope wind component was strong enough to overcome the usual up-slope thermal winds and also the normal tendency for fire to burn uphill. Actual fire behavior was very close to that indicated by the wind pattern map for 1200 hours (fig. 11). No effect of the fire itself on the wind pattern of any significance to fire behavior was noted.

Of particular interest in fire control is the fire spotting across Cache Creek Valley. Some spotting occurred over much of the area on the lee side of the fire. There was a very definite concentration of spots, however, about one-third the way up the west-facing slopes on the east side of the valley opposite the fire--a distance of about three-quarters of a mile. This same phenomenon of fire spotting a considerable distance across a valley and part way up the slope was noted in a previous survey.1/ In this former case it appeared probable that the warm air from the fire "rode" across cooler air over a reservoir in the valley, carrying burning debris with it. In the present case it is likely that a similar action

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1/ Countryman, C. M. and Schroeder, M. J., Prescribed burn fireclimate survey 2-57 CF&RES Tech. Paper 31, 1959.

occurred. The strong cross valley wind circulation, shading of the valley floor by riparian vegetation, and attenuation of the sun's radiation by smoke would all tend to prevent a buildup of heated air in the valley. The warm air and gases from the fire area could thus be expected to be warmer than air in the valley and would flow over any cooler air in the valley. The behavior of the main convection column indicated this kind of action was taking place; the column did not follow the pre-fire wind flow down-slope into the valley but crossed above the valley to the slopes beyond. More extensive surveys--both in the horizontal and vertical directions--are needed to substantiate this possible effect.

CONCLUSIONS

Of particular importance to fire control and fire weather forecasting was the prevalence of down-slope winds in the afternoon in this area. Not only was the wind direction opposite to that expected from the classical theory of up-slope winds during the daytime in mountain areas, but the down-slope wind speeds were also greater than could be expected with up-slope thermal winds. The down-slope winds were of sufficient force to exert almost complete control of the behavior of the fire.

These afternoon down-slope winds have been observed in coastal areas from one end of California to the other. There is also some evidence they may occur in parts of the Sierra Nevada as well. Little is known of the frequency and duration of these winds or of the conditions that lead to their onset. We must conclude from this study and from observed effects on wildland fires, however, that these winds are of major importance in fire behavior and control and must be given high priority in fire-climate studies.